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Fracture Trauma in a Medieval British Farming Village

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ABSTRACT Farming is among the three most hazardous occupations in modern society and perhaps also held a similar position during the medieval period. The goal of this study was to determine if there is a significant difference in frequencies and patterns of longbone fracture trauma observed between rural and urban activity bases that distinguish farming as a particularly dangerous occupation during the medieval period. The longbones of 170 individuals excavated from Raunds, a rural medieval British site (10th–12th centuries AD) were examined for fractures and compared to data collected from four contemporary British medieval sites, one rural and three urban. The fracture frequency for the Raunds individuals (19.4%) was significantly different from the urban sites (4.7–5.5%). Female fractures were characterized by injury to the forearm, while the males were predisposed to diverse fracture locations. Clinical research provided a source of documented farm-related trauma from North America and Europe where the crops and animals raised, the manual chores performed, and the equipment used in traditional or small-scale farms have changed little in form or function since the medieval period. Nonmechanized causes of injury contribute to approximately 40% of all modern farm-related injuries and are attributed to falls from lofts and ladders, animal assaults and bites, and falls from moving vehicles. These hazardous situations were also present in the medieval period and may explain some of the fracture trauma from the rural sites. A high fracture frequency for both medieval males and females is significantly associated with farming subsistence when compared to craft-orientated urban dwellers. Am J Phys Anthropol 109:229–243, 1999.

Agriculture ranks among the top three most dangerous occupations in industrialized nations, accompanied by construction and mining. In many regions it is the leading cause of fatal and nonfatal injuries and therefore, the identification of physical hazards is an essential topic in clinical research (Brison and Pickett, 1992; Nordstrom et al., 1995; Purschwitz and Field, 1990). Epidemiological study of farming-related trauma identifies the etiology of injury, designs preventative strategies, creates safer equipment, and disseminates knowledge to reduce high trauma statistics (e.g., Purschwitz and Field, 1990; Stallones, 1990; Nordstrom et al., 1995). While these modern investigations of occupational trauma strive to prevent injury in present-day populations, they also provide insight with which to assess trauma among archaeological populations.

Fracture trauma are common pathological lesions observed in archaeological skel-

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etal material and represent the accumulation of physically traumatic events in an individual's life that resulted in broken bones. While observations of trauma are conscientiously reported during a skeletal analysis, tabled in skeletal reports, and adeptly described, there remains a paucity of systematic investigations at the populational and etiological levels.

Early studies of archaeological trauma were either case studies of violence (e.g., Hawkes and Wells, 1975) or summaries covering an immense time span with equally diverse recording methods (e.g., Angel, 1974; Grimm, 1980; Smith and Jones, 1910). Since then, studies of trauma have emerged as investigations that integrate physical and cultural factors within a specific environmental context into the interpretation of the trauma pattern observed. The report by Lovejoy and Heiple (1981) of Late Woodland hunter-gatherer longbone fractures at the Libben site in Northern Ohio was perhaps the earliest in-depth methodical trauma study conducted at the populational level, and it ushered in a new standard for paleotrauma research. Numerous methodical and interpretive issues were addressed: a systematic data collection, the expression of frequency of fractured bones per bone type in addition to fractures per individual, accidental vs. intentional trauma, and years at risk of trauma. Recently, Larsen (1997) reviewed more current research areas in populational investigations of ancient trauma, e.g., the role of elemental patterning in determining whether a lesion was due to violence or accident (e.g., Grauer and Roberts, 1996; Kilgore et al., 1997), the effects of immigration (e.g., Ubelaker, 1994), subsistence strategy (e.g., Goodman et al., 1984), industrialization (e.g., Jiminez, 1994), ritualized violence (e.g., Harman et al., 1981), and child abuse (e.g., Walker et al., 1997). Paleotrauma research has advanced significantly, although much of the focus remains directed towards violence, i.e., both domestic and external warfare (Larsen, 1997). Other areas such as occupational trauma, however, remain neglected.

Stirland (1988) previously cautioned about attempts to associate specific occupations with paleopathology, especially when the activities are known only through artifacts, but stressed the need for rigorous similarity studies between temporally and/or geographically contemporary groups so that group activity or general occupation could be assessed. However, the greatest obstacle for such intersite comparisons of paleotrauma that seek to examine variables such as age and sex variation, environment, subsistence strategy, or lifestyle is the lack of use of standard recording procedures that facilitate comparison, although various protocols and recommendations exist (e.g., Buikstra and Ubelaker, 1994; Lovell, 1997; Roberts, 1991; Thillaud, 1996). This investigation will address this potential by examining fracture trauma as a product of daily living in a specific environment, in this case, rural medieval Britain.

Farming is a unique "occupation" as it is a lifestyle composed of multiple activities, rather than one specific occupation, performed in a simple setting that serves as both a residence and workplace (e.g., Stallones, 1990), and allows for only intermittent escape to different surroundings, a situation amplified in the isolated medieval village. This study will assess the longbone fracture patterns and frequencies from a rural medieval British skeletal sample and compare the results to those of four other British samples, one rural and three urban, dated to the medieval period, from which data were similarly recorded. With the temporal and geographic components constant, the role of the living and working environment of these sites can be explored as an injury risk factor. By comparing longbone fracture patterns and frequencies of rural medieval British samples to those of their contemporary urban samples, it is possible to determine whether the activity complex associated with farming posed an occupational hazard in antiquity as it does in the present day.

MATERIALS AND METHODS

The sample

Raunds Furnells (NGR 999733) was a small agricultural community located in the Nene Valley of the English East Midlands just northwest of the present village. The site was occupied from the late 6th–15th

centuries AD, and consisted of approximately 40 villagers at any one time. The Christian Saxon cemetery from which this skeletal sample derived was established during the 10th century and used for about 200 years (Boddington, 1987). A total of 363 burials was excavated by the Northamptonshire Archaeology Unit from 1977–1980, and the remains are currently stored at the Department of Archaeological Sciences at the University of Bradford. Only adults of known sex as determined by the skeletal analysis of Powell (1982) were included in this investigation.

Recording of fractures

The longbones (clavicle, humerus, radius, ulna, femur, tibia, and fibula) of each individual were identified as present (90%+ bone present), incomplete (50–90% bone present), fragmentary (<50% bone present), or absent. Each bone was examined for evidence of antemortem or perimortem fracture. Incomplete bones with fractures and all complete bones formed the observable corpus.

The side affected and the position of fracture (proximal, middle, or distal third of the shaft) were recorded for each bone. The fracture type was assigned as transverse, oblique, spiral, comminuted, incomplete, impacted, compressed, crush, or avulsion, following the definitions most recently summarized by Lovell (1997). This information assists in determining the type of energy that caused the fracture, such as a direct force resulting from a blow, an indirect force due to fall, or repetitive stress.

Metric data were obtained by macroscopic and radiographic methods. The fractured bones were radiographed anteroposteriorly and mediolaterally, using X-ray equipment in the Archaeological Sciences Department at the University of Bradford. The unit used was a Hewlett Packard Faxitron, model 43805. Sixty kilovolts for 2.25 min were required for radiographs of the clavicle, ulna, radius, and fibula. The humerus, femur, and tibia needed 60 kv at 2.50 min.

The radiograph of the fractured bone allowed alignment, apposition, and overlap of the broken bone fragments to be measured, using the method recently illustrated by Grauer and Roberts (1996). “Alignment” refers to the angle created by the distal end of the fractured bone relative to the axis of the proximal end. “Apposition” is the horizontal displacement of the distal fragment from the axis and is expressed as the percentage of the surface area united by the two fragments. Each fractured bone and its opposite were measured for length. This difference in bone length was verified by the overlap observed on the radiograph, where overlap measured the amount of the distal fragment that was then parallel to the proximal fragment. Any overlap shortens the bone and creates complications for joint movement. Likewise, lengthening or distraction of the traumatized bone will also hinder mobility. These measurements provide a quantified description that allows the success of bone healing to be determined using a clinical model described by Grauer and Roberts (1996). The allowable linear deformity varies among bones, with that of the lower limb being more sensitive to changes in length due to the weight-bearing function.

Most fractures heal successfully, but problems may arise that affect the function of the bone, joint, or soft tissue, or threaten the survival of the individual. General complications develop rapidly after the injury occurs and are not visible in skeletal paleopathology due to their acute and fatal nature. Such developments include crush syndrome and tetanus that may both result in death, gangrene that may lead to limb amputation, and fat embolism, the catalyst for cardiovascular accident. Local complications may occur shortly after the injury or years later and are visible in skeletal remains. Fractured bones were examined for periosteal lesions and osteomyelitis. The presence of osteoarthritis, mal-union, post-traumatic ossification, atrophy, and avascular necrosis determined joint alterations due to bone fracture.

Analysis

The fracture frequency was calculated for the entire longbone sample and each bone

TABLE 1. Comparative medieval urban cemetery populations[1]

Site	Date (AD)	Population N	Males n	Females n
St. Helen-on-the-Walls	11–17th century	351	139	73
St. Nicholas Shambles	10th century–1550	1,041	247	285
Blackfriars	1263–1538	250	148	64

[1] N, total number of individuals in the population sample; n, number of individuals for whom biological sex was assigned.

TABLE 2. Age, sex, and fracture distribution at Raunds[1]

	Female fractures			Male fractures			Total fractures		
Age at death	N	n	%	N	n	%	N	n	%
18–24	33	3	9.1	20	4	20.0	53	7	13.2
25–34	18	5	27.8	22	3	13.6	40	8	20.0
35–44	7	2	28.6	24	6	25.0	31	8	25.8
45+	15	3	20.0	25	7	28.0	40	10	25.0
Undetermined	4	0	0.0	2	0	0.0	6	0	0.0
Total	77	13	16.9	93	20	21.5	170	33	19.4

[1] N, number of individuals; n, number of individuals who sustained one or more fractures.

type. This calculation is expressed as follows:

$$\text{Fracture frequency} = \frac{\text{Number of elemenets fractured}}{\text{Total number of elements observed}} \times 100\%$$

An extension of this equation was used to express the fracture frequency of individuals with fractures and fracture pattern distributions within the smaller fracture sample for each site. These data were compared to those calculated from the contemporary rural Anglo-Saxon sample from Jarrow Abbey (Wells, n.d.) that consisted of 57 females and 83 males. The injury patterns of the two rural samples were compared to fracture frequencies calculated from data collected by the original investigators of three urban medieval samples to assess the difference, if any, between rural and urban communities. The urban sites included St. Helen-on-the-Walls, hereafter referred to as St. Helen's (Grauer and Roberts, 1996), St. Nicholas Shambles, hereafter referred to as St. Nicholas (White, 1988), and Blackfriars (Mays, 1991). The demographic distribution of the skeletal material from the comparative urban samples is described in Table 1. Chi-square tests were used to determine statistically significant variations in the presence of fracture between the sexes and among the sites, as well as the fracture location; Yate's correction for continuity was applied to small samples. The significance level chosen was 0.05.

RESULTS

Raunds fracture pattern and frequencies

The demographic and fracture profile of the Raunds adults is given in Table 2. The fracture frequency for *individuals* was 19.4%, as 33 of the 170 people sustained one or more fractures. Of the 33 traumatized persons, 20 were male (60.6%) and 13 were female (39.4%). Table 3 provides a categorized summary of the total bones observed and adult fractures from the Raunds sample. A total of 1,115 longbones was examined and 39 healed fractures were recorded, resulting in a *longbone* fracture prevalence of 3.5%. There were no perimortem fractures.

The distribution of fractured bones between the sexes is tabulated in Table 4. Males had 22 injuries (56.4%), and females accounted for the remaining 17 lesions (43.6%). The ulnae (Fig. 1) and radii of the females sustained the greater amount of fractures among the female fractures (70.6%), while the clavicle accounted for 17.6% of traumatized longbones. The tibia and fibula exhibited one lesion each (5.9%); there were no cases of humeral or femoral trauma. The most commonly broken bone

TABLE 3. Frequency of fractured bones at Raunds[1]

Element	Right fractures N	Right fractures n	Right fractures %	Left fractures N	Left fractures n	Left fractures %	Total fractures N	Total fractures n	Total fractures %
Clavicle	84	6	7.1	87	6	6.9	171	12	7.0
Humerus	87	0	0.0	91	2	2.2	178	2	1.1
Ulna	83	5	6.0	81	1	1.2	164	6	3.7
Radius	80	5	6.3	87	3	3.5	167	8	4.8
Femur	97	1	1.0	89	1	1.1	186	2	1.1
Tibia	86	1	1.2	77	2	2.6	163	3	1.8
Fibula	40	1	2.6	46	5	11.1	86	6	7.0
Total	557	19	3.4	558	20	3.6	1115	39	3.5

[1] N, total number of elements observed; n, number of elements with fractures.

TABLE 4. Distribution of fractures by bone element and sex[1]

Element	Females Fractures n	Females % female fractures	Females % total fractures	Males Fractures n	Males % male fractures	Males % total fractures	Total Fractures n	Total % total fractures
Clavicle	3	17.6	7.7	9	40.9	23.1	12	30.8
Humerus	0	0.0	0.0	2	9.1	5.1	2	5.1
Ulna	6	35.3	15.4	0	0.0	0.0	6	15.4
Radius	6	35.3	15.4	2	9.1	5.1	8	20.5
Femur	0	0.0	0.0	2	9.1	5.1	2	5.1
Tibia	1	5.9	2.6	2	9.1	5.1	3	7.7
Fibula	1	5.9	2.6	5	22.7	12.8	6	15.4
Total	17	100.0	43.6	22	100.0	56.4	39	100.0

[1] n, number of fractures.

among the males was the clavicle (40.9%), followed by the fibula (22.7%). Male ulnae exhibited no evidence of injury; two fractures (9.1%) occurred to each of the other longbones. When the sexes were pooled, the majority of fractures occurred to the clavicle (30.8%), followed by the radius (20.5%); the humerus and femur were rarely injured (5.1% each). A χ^2 analysis between biological sex and presence of fracture did not indicate a significant relationship ($\chi^2 = 0.58$, df $= 1$, $P = 0.448$). A significant relationship was present between the sexes and forearm fractures ($\chi_c^2 = 10.67$, df $= 1$, $P = 0.00097$).

The injury distribution pattern was further defined by the examination of fracture location and type (Table 5). The distal third of the bone was most frequently traumatized (61.5%), while the other injuries were closely distributed between the proximal (20.5%) and middle (18.0%) thirds. The most common type of fracture was oblique (56.4%), which suggests an indirect stress on the bone; transverse breaks, the result of direct impact, followed in frequency (25.7%). The remaining injuries were distributed between incomplete and impacted fractures.

Six of the 33 injured persons (18.2%) displayed multiple trauma. Three females (R5094B, R5295, and R5299) had fractured forearms (Fig. 2), and one female (R5051) sustained simultaneous injuries to the bones of the lower leg. One male, R5062, exhibited a fracture to the left humerus (Fig. 3) and right femur, while the clavicles of a second male (R5183) were broken.

Although complications occurred in this sample (Table 6), most were not severe, and the healing process was successful. Periosteal lesions due to bone surface infection or remnants of the healing process were most frequently observed in 35.9% of the traumatized bones, but may not have been due solely to the fracture. Osteomyelitis, the more severe infection caused by the external contamination of an open wound when the broken bone penetrates the skin surface, infected 12.8% of the bones (Fig. 4). Joint movement may have been restricted in some individuals, especially in the upper limb due to osteoarthritis (17.9%), avascular necrosis (5.1%), or some form of linear displacement whether angular, horizontal, or vertical (combined occurrence in 20.6% of fractures).

Fig. 1. Distal right ulna fracture (R5100).

There was no evidence of posttraumatic ossification at any fracture site.

Raunds and Jarrow Abbey

When compared to the contemporary rural sample from Jarrow Abbey (Table 7), the prevalence of fractures among the longbones observed was similar between Raunds (3.5%) and Jarrow Abbey (2.2%), and the difference was not significant ($\chi^2 = 2.69$, df = 1, $P = 0.101$). The Raunds group, however, exhibited a higher fracture frequency (19.4%) among injured individuals than Jarrow Abbey (10.7%), which was significant ($\chi^2 = 4.44$, df = 1, $P = 0.035$). As at Raunds, there was no significant relationship between biological sex and the presence of fractures at Jarrow Abbey ($\chi^2 = 0.25$, df = 1, $P = 0.619$), but a significant relationship was found between the sexes and forearm fractures ($\chi_c{}^2 = 3.981$, df = 1, $P = 0.02925$).

Fractures to the upper body accounted for the majority of trauma in the Raunds and Jarrow Abbey samples, with humeral and clavicular fractures occurring only in the Raunds group (Table 8). When the two rural samples were pooled, a significant difference was demonstrated between the sexes and upper body fractures ($\chi_c{}^2 = 4.839$, df = 1, $P = 0.02497$), as well as forearm fractures ($\chi^2 = 14.3156$, df = 1, $P = 0.00016$). The rural females were predisposed to fractures of the forearm, while the location of male lesions was more variable.

Rural vs. urban sites

When the fracture frequencies for the *total longbones* observed were compared among the three urban samples (Table 7), it was found that there was a significant difference in longbone fracture frequencies among the sites ($\chi^2 = 30.469$, df = 2, $P < 0.0000$). This difference was insignificant between St. Helen's and Blackfriars, which had similar longbone fracture frequencies ($\chi^2 = 0.0141$, df = 1, $P = 0.9055$). A comparison of fracture prevalence for *individuals* among the urban sites, however, revealed that there was no significant difference ($\chi^2 = 0.186$, df = 2, $P = 0.911$). This is attributed to the number of multiple injuries sustained by the individuals from the St. Nicholas sample. There was no significant difference between the urban sexes and forearm injury, although a significant difference was approached when upper body fractures between the sexes were evaluated ($\chi_c{}^2 = 3.131$, df = 1, $P = 0.0572$).

When the *overall longbone fracture frequencies* were compared between the rural and urban sites (Table 7), St. Nicholas was the only urban site that exhibited a longbone fracture frequency insignificantly different from that of the rural sites (Raunds: $\chi^2 =$

TABLE 5. Fracture pattern analysis[1]

	Position on shaft (n)			Fracture type (n)			
Element	Proximal	Middle	Distal	Transverse	Oblique	Incomplete	Impacted
Clavicle	3	3	6	3	6	3	0
Humerus	2	0	0	0	0	0	2
Ulna	0	1	5	1	3	2	0
Radius	1	1	6	2	6	0	0
Femur	1	1	0	1	1	0	0
Tibia	0	1	2	0	3	0	0
Fibula	1	0	5	3	3	0	0
Total	8	7	24	10	22	5	2
Percent	20.5	18.0	61.5	25.7	56.4	12.8	5.1

[1] n, number of fractured bones.

0.2078, df = 1, P = 0.649; Jarrow Abbey: χ^2 = 2.842, df = 1, P = 0.0916). The *frequency of individuals* (males and females combined) sustaining trauma from rural sites ranged from 10.7–19.4%, while the fracture prevalence for individuals from urban sites spanned 4.7–5.5%. When the lower rural individual fracture frequency of Jarrow Abbey (10.7%) was compared to those of the urban sites, a significant difference was observed with samples from St. Helen's (χ^2 = 5.018, df = 1, P = 0.0251) and Blackfriars (χ^2 = 4.559, df = 1, P = 0.0327), while the St. Nicholas group approached significance (χ^2 = 3.50, df = 1, P = 0.0613). There was a highly significant difference in the individual fracture frequencies between Raunds and the urban sites (Blackfriars: χ^2 = 20.394, df = 1, $P < 0.0001$; St. Helen's: χ^2 = 31.184, df = 1, $P < 0.0000$; St. Nicholas: χ^2 = 14.259, df = 1, $P < 0.0002$). The combined individual fracture frequency varied significantly between the rural and urban sites in all cases.

Fig. 2. Associated left ulna and radius fracture (R5295).

Among the males, those from the rural sites experienced a greater fracture frequency, although this was significant only among the Raunds males when compared to their urban counterparts (Blackfriars: χ^2 = 16.156, df = 1, $P < 0.0001$; St. Helen's: χ^2 = 13.758, df = 1, P = 0.0002; St. Nicholas: χ^2 = 9.17, df = 1, P = 0.0017). When the samples were pooled, however, rural males sustained significantly more fractures than urban males (χ^2 = 15.253, df = 1, $P <$ 0.0001).

Rural females displayed a much higher fracture frequency than urban females. A significant difference was found between the fracture prevalence for the females from

Fig. 3. Fractured left humerus with avascular necrosis of humeral head (R5218).

Jarrow Abbey when compared to St. Helen's ($\chi^2 = 6.765$, df = 1, $P = 0.0093$) and Blackfriars ($\chi_c{}^2 = 4.57$, df = 1, $P = 0.02999$), but not St. Nicholas. A higher fracture prevalence existed for Raunds females when compared to all of the urban female groups (Blackfriars: $\chi_c{}^2 = 4.791$, df = 1, $P = 0.0265$; St. Helen's: $\chi^2 = 16.609$, df = 1, $P < 0.0001$; St. Nicholas: $\chi_c{}^2 = 5.998$, df = 1, $P = 0.0132$). When the samples were pooled, a significant difference was observed in the prevalence of fractures between females at rural and urban sites ($\chi^2 = 19.286$, df = 1, $P < 0.0001$).

Both males and females from the rural sites suffered a higher prevalence of longbone fractures than persons from the contemporary urban settings. Females were predisposed to upper body fractures in both environments, although the rural females were particularly vulnerable to forearm fractures. These results suggest that there was a distinct difference in fracture frequencies between both males and females in rural and urban environments in medieval Britain.

DISCUSSION

Life and subsistence in the medieval farming village

In order to evaluate the role of the medieval rural environment in fracture etiology, it is necessary to briefly review the daily activity and lifestyles of the medieval peasant. Daily subsistence activities included routine chores such as those illustrated by the "Labors of the Months," a recurrent medieval theme in sculpture, painting, stained glass, architecture, and manuscripts. These scenes depict farming activities as functions of the season, such as plowing in March, threshing in September, and killing hogs in December (e.g., Henisch, 1995; Webster, 1970). In addition to recording activity and the associated perishable ecofacts, these icons also provide visual evidence of information not detectable from the archaeological record alone, such as the posture and actions required to perform the activity, the type of equipment used, who usually performed the task, and the role of animals in the local economy.

Milk, eggs, cheese, and vegetables made up a large portion of the peasant diet and were less frequently traded. Butter and cheese were particularly valued, as they could be stored for longer periods of time than the 2-day life span of fresh milk (Hellier and Moorhouse, n.d.). Chicken and geese were relatively cheap to maintain since they did not require a special diet. They were therefore plentiful and provided a continuous source of eggs (Grant, 1994). Crops such as barley, wheat, oats, and rye were common and the labor required for a successful bounty was part of the annual routine: plowing, sowing, harvesting, threshing, winnowing,

TABLE 6. Fracture complications[1]

Element	Deformity n	Periosteal lesions n	Osteomyelitis n	Osteoarthritis n	Shortening n	Mal-union n	Avascular necrosis n
Clavicle	1	1	0	1	1	1	0
Humerus	0	0	1	1	2	0	2
Ulna	0	3	1	1	0	0	0
Radius	0	5	0	4	0	1	0
Femur	0	0	1	1	0	1	0
Tibia	0	2	1	0	1	0	0
Fibula	0	3	1	1	0	0	0
Total	1	14	5	7	4	3	2
Percent	2.6	35.9	12.8	17.9	10.3	7.7	5.1

[1] n, number of fractured bones.

Fig. 4. Osteomyelitis of femoral shaft (R5369).

and milling (Grube, 1934; Langdon, 1994). Apple, pear, and nut trees comprised the orchard, while wild nuts and berries were also gathered to enhance the diet (Dyer, 1983). Peasants living near woodlands hunted or poached rabbit, deer, boar, birds, and squirrel, especially during the harsh winter months. Husbandry was practiced along with agriculture, rendering each family unit self-sufficient. Pigs were kept strictly for meat, cattle provided milk, and sheep produced milk and wool. Horses, bulls, and oxen were used primarily for labor, although their meat was eaten out of necessity (Grant, 1994). Some households supplemented their income with dairying, brewing, butchering, baking, thatching, milling, timber production, and carpentry, or by selling agricultural produce to neighboring towns (Bennett, 1987).

Men were responsible for heavier labor and work located at a distance from the homestead, such as fieldwork, plowing, transporting, fishing, tree felling, and herding. Females assisted in field chores such as planting, weeding, and gleaning, but the majority of their work focused on the *croft* (garden) at home. Here, activities included gardening, fowling, brewing, baking, tending the orchards, milking cows, making butter and cheese, spinning, and weaving (Bennett, 1987; Goldberg, 1992). The close proximity to the house allowed women to provide vigilant child care, while attending to food preparation for the family and workers (Murdock and Provost, 1973). It was essential for females to remain flexible during the peak seasons of harvest and planting to assist in the fields. Men reciprocated by performing tasks closer to home during the

TABLE 7. *Comparison of fracture frequencies at medieval rural and urban sites*[1]

Site	Total bones	Total fractures	%	Female fractures			Male fractures			Combined fractures		
				N	n	%	N	n	%	N	n	%
Rural												
Raunds	1,115	39	3.5	77	13	16.9	93	20	21.5	170	33	19.4
Jarrow Abbey	697	15	2.2	57	7	12.3	83	8	9.6	140	15	10.7
Urban												
St. Helen's	4,938	41	0.8	285	11	3.9	247	18	7.3	532	29	5.5
St. Nicholas	296	12	4.1	71	3	4.2	90	5	5.6	161	8	4.9
Blackfriars	1,861	16	0.9	64	3	4.7	148	7	4.7	212	10	4.7

[1] N, number of individuals; n, number of individuals with fractured bones.

TABLE 8. *Comparison of fracture location at rural and urban sites*[1]

Site	Clavicle	Humerus	Ulna	Radius	Femur	Tibia	Fibula	Total
Females								
Raunds (n)	3	0	6	6	0	1	1	17
Percent of total	17.6	0.0	35.3	35.3	0.0	5.9	5.9	100.0
Jarrow Abbey (n)	0	0	3	3	0	0	1	7
Percent of total	0.0	0.0	42.9	42.9	0.0	0.0	14.3	100.0
St. Nicholas (n)	1	0	2	2	0	0	0	5
Percent of total	20.0	0.0	40.0	40.0	0.0	0.0	0.0	100.0
Blackfriars (n)	1	0	1	2	0	0	0	4
Percent of total	25.0	0.0	25.0	50.0	0.0	0.0	0.0	100.0
Males								
Raunds (n)	9	2	0	2	2	2	5	22
Percent of total	40.9	9.1	0.0	9.1	9.1	9.1	22.7	100.0
Jarrow Abbey (n)	0	0	0	5	1	1	1	8
Percent of total	0.0	0.0	0.0	62.5	12.5	12.5	12.5	100.0
St. Nicholas (n)	0	2	2	2	0	1	0	7
Percent of total	0.0	28.6	28.6	28.6	0.0	0.0	14.2	100.0
Blackfriars (n)	0	2	3	2	2	2	1	12
Percent of total	0.0	16.7	25.0	16.7	16.7	16.7	8.1	100.0

[1] n, number of fractured elements; the distribution of fractures by sex was unavailable for St. Helen's.

winter months, such as butchering and dairying (Bennett, 1987). Both sexes in poorer households hired themselves out when additional workers were in demand, especially during the harvest (Bennett, 1987).

Medieval farming, therefore, was not a distinct occupation with specific tasks, but rather a way of life composed of a medley of activities required to maintain the household throughout the year. The actions involved in accomplishing these tasks and the surroundings in which they were performed provided the arena for potential injury.

Fracture etiology in modern farm settings

Clinical investigations of farm living reveal that residents and hired laborers are exposed to greater occupational and environmental hazards than any other occupation (e.g., Cogbill et al., 1991; Jones, 1990; Nordstrom et al., 1995; Purschwitz and Field, 1990), but was this also true in antiquity? It may be argued that the high incidence of modern farm injury is due to increased mechanization and heavy equipment such as tractors, combines, and harvesters, but current epidemiological research finds that fractures due to nonmechanized causes still account for a substantial majority (about 40%) of nonfatal farming injuries. For example, an extensive 12-year investigation of agricultural trauma in rural Wisconsin, Minnesota, and Iowa discovered that of 739 cases of farm-related injuries, 225 (30%) were attributed to falls, kicks, or assaults by farm animals, while 77 individuals (10%) fell from the hayloft, hay wagon, or silo (Cogbill et al., 1991). The study by Jones (1990) of trauma in an American Amish community in Ohio described fracture patterns in a "traditional" farming community and thus provides a source of injury mechanisms that may also have been present in a

medieval British farming village such as Raunds. The Amish practice a frugal, preindustrial agricultural lifestyle and avoid modern technological innovations such as electricity, telephones, engines, and automobiles (e.g., Brewer and Bonalumi, 1995). The division of labor is clearly defined: males are employed predominantly as farmers although some now work in the community as carpenters, blacksmiths, carriage makers, and butchers, while women tend the garden, process and prepare food, provide child care, and create handicrafts (Hostetler, 1993). In Jones (1990), 60 cases of trauma were observed in 272 hospital admissions over a 3-year period. Injuries that occurred during chore performance accounted for 58.3% of fractures and were attributed to the following etiologies: throws from a buggy or saddle (18.3%), horse kicks (5%), falls predominantly from a ladder or hayloft (28.3%), and encounters with horse-drawn equipment (6.7%).

The dominance of animal-related injuries is echoed in clinical studies of automated farming sectors (e.g., Barber, 1973; Boyle et al., 1996; Busch et al., 1986; Chitnavis et al., 1996). While a portion of injuries are attributed to falls over the family pet that usually result in fractures to the upper extremities (e.g., Björnstig et al., 1991), more aggressive damage is associated with falls from horses, bovine assaults, and falls from animal-drawn vehicles (e.g., Barber, 1973; Björnstig et al., 1991; Busch et al., 1986). An association with beef and dairy farms presents an increased hazard for all agricultural workers, where injury may occur from close contact with the animal during feeding, milking, dehorning, calving, and foot treatment (e.g., Boyle et al., 1996; Brison and Pickett, 1992; Pratt et al., 1992).

Virtually everyone residing on a farm, including children and the elderly, is involved with daily chores and therefore vulnerable to injuries unique to a farm setting (e.g., Purschwitz and Field, 1990; Vane et al., 1993; Wilk, 1993). When women are active in farm chores, males generally exhibit a greater proportion of injuries, such as 2.8:1 (Pratt et al., 1992) and 3:1 (Stueland et al., 1997), although Zhou and Roseman (1994) found that females incurred more injuries than males. The greater propensity for male trauma has been attributed to the riskiness of male labor (Pratt et al., 1992), the number of hours worked (Stueland et al., 1997), and being the owner/operator (Nordstrom et al., 1995; Pratt et al., 1992). The majority of all female farm injuries, even in a modernized operation, are attributed to animals, especially dairy cows, with short falls in the barn being second; the arms are the most frequent injury location (e.g., Brison and Pickett, 1992; Stueland et al., 1997). During peak harvest seasons, a work reciprocity exists, and all able bodies may be recruited to perform essential tasks, thereby exposing everyone to the hazards of the activity (e.g., Hostetler, 1993; Stueland et al., 1997). It is during these intense periods that more injuries occur (e.g., Brison and Pickett, 1992; Pratt et al., 1992) and may be attributed to the inexperience of temporary workers or exhaustion.

Small farm operation is unregulated and therefore mandatory retirement is not essential (e.g., Purschwitz and Field, 1990). As a result, many older adults continue to perform tasks that physically challenge their aging bodies. Physiological deterioration such as failing eyesight and hearing, slow reaction time, impaired vibration of the lower limbs, vertigo, and impaired coordination in the dark increases with advanced age and therefore is an added factor to farm injury susceptibility (Buhr and Cooke, 1959; Garroway et al., 1979; Zylke, 1990). Bone loss due to osteoporosis in older males and females creates a more fragile, brittle bone that breaks easily, especially during low-energy traumatic impacts caused by falling and tripping. Longbone sites that are particularly vulnerable include the proximal humerus, distal radius, proximal femur, and proximal tibia (Jónsson et al., 1992). However, while rural activities produce an increased general injury risk, a rural lifestyle results in a decreased incidence of osteoporotic fracture in modern populations and is credited to the higher activity levels of the farm residents that creates a greater maximum bone mass (e.g., Agarwal, 1980; Aström et al., 1987; Jónsson et al., 1992).

Children are overlooked as members of the agricultural workforce, even though they

constitute a large majority of the injuries reported (Brison and Pickett, 1992; Cogbill et al., 1991; Vane et al., 1993). Common sources of fatal injury to children include drowning in irrigation ditches, suffocation in grain bins, animals, and farm machinery, while nonfatal injuries are ascribed to falls and animals. A child may not necessarily be working when an accident occurs, but because they often accompany the parent during chores, they are also exposed to similar workplace dangers (Wilk, 1993).

It is clear that a substantial number of agricultural injuries on modernized farms are related to nonmechanical factors such as farm animals and falls. It would seem reasonable that the longbone fracture pattern at Raunds may reflect the complex of activities associated with the “traditional” farming lifestyle.

The role of farming in the Raunds fracture pattern

Several common injury sources exist between the nonmechanized aspects of modern farming and the medieval farming environment, such as the role of animals in the economy, animal-drawn vehicles and equipment, structures such as haylofts and silos, the use of ladders, harvesting, and butchering. Nonmechanical equipment used in antiquity has not changed functionally or morphologically over time and is similar to that used in traditional farming communities (Steane, 1984). Langdon (1994) compiled a list of hand tools available on a well-equipped medieval farm with their associated activities; tools such as axes, mallets, sickles, forks, ladders, and wheelbarrows were used much as they are today. Therefore, the injury etiology, pattern, and frequency sustained by ancient peoples while using this equipment or performing manual farm chores should also be similar.

Injuries sustained by rural females from Raunds and Jarrow Abbey are characterized by distal, oblique fractures to the forearm, which are associated with indirect forces due to tripping or short falls caused by a shift in body weight and loss of center of gravity. When upright balance is lost due to a slip, the individual falls backward and instinctively extends the arms to break the fall, thereby placing additional stress on the forearm’s shaft. During a trip, the step is obstructed and the body falls forward; the head and trunk resist by arching back while the arms abduct to regain balance to absorb the impact force. Likewise during a stumble, due to erratic or unstable foot movement, the body attempts to regain its center of gravity by arm abduction and by doing so, the arms are again unprotected. In any case, should balance be recovered, stress is placed on the lower leg in the process, predisposing it to fracture or sprain (Sacher, 1996). Women and children were likely prone to tripping, slipping, or stumbling while procuring, transporting, and processing items such as fuel, water, milk, eggs, grains, fowl, and produce. Dairying, a task relegated to medieval women (Bennett, 1987), would have exposed females to tibia injury, which is frequently encountered during the course of milking the animal (Busch et al., 1986).

In this northern region of England, ox-pulled carts predominated during the early medieval period (Langdon, 1994). The heavier ox-drawn carts were much larger than the horse-drawn vehicles and had spoked rather than solid wheels, a sinister web for an unguarded leg. By the eleventh century, plough technology allowed for more efficient breaking of the ground and ridging. Teams of 6–8 horses or oxen were required to power this equipment (Langdon, 1994). While men were alleviated of some injury from maneuvering the human-powered push-plough, they now worked intimately with large draft animals and faced a different occupational hazard. Falls from wagons or horses, or being caught under overturned vehicles, most probably happened in antiquity, with males the more frequent victim, since they habitually traveled to the fields and worked with the animal teams. Injuries received in these situations are identified clinically by lesions typical of direct blows, such as clavicular or midshaft transverse breaks, especially when the more robust humerus or femur are involved (e.g., Chitnavis et al., 1996). Falls from heights are commonly associated with lower limb and clavicle fractures, as individuals typically land on their shoulder or lower leg (Muir and Kanwar, 1993). These types of injuries

are typical of the diverse fractures observed among the Raunds males.

Living conditions, combined with the deterioration of the senses and motor skills, were a particular bane to the elderly. Small (4.0–5.0 m $\times$ 8.0–15.0 m), low-ceilinged houses afforded shelter to both humans and animals in one long room before separating the living area from the barn in later periods (Astill, 1994). A central hearth provided the internal heating and light source, but left the perimeter and entrance in darkness, although candles, ceramic lamps, and lanterns generated additional lighting sources (Astill, 1994). The cohabiting smaller animals such as dogs, cats, rats, and fowl also functioned as mobile or sedentary obstacles, and chances of stumbling were heightened by inadequate lighting even during the daytime, since there were few windows. While this living environment would challenge the physical dexterity of any individual, when combined with the sensory impairments of aging, a rugged terrestrial environment, and daily farming activity, a considerable number of daily hazards confronted older adults.

Fractures sustained by Raunds adults over 45 years of age accounted for 25% of all longbone lesions. Three of 15 (20%) females presented injuries: one had a clavicular fracture, one exhibited a midshaft break to the forearm while pronated, and the third had a Colles' and distal ulna fracture, all typical of injuries received during a short fall (Loder and Mayhew, 1988; Sacher, 1996). Injuries displayed by 7 older males were also typical outcomes of falls (4 clavicles, 2 distal fibulae, and 1 radius) and accounted for 28% of the male fractures. However, these injuries did not necessarily occur in old age and represent the accumulation of trauma at the time of death. These data also contradict the clinical evidence for increased older female trauma due to osteoporosis, but endorse the advantages of a physically active farm life.

Five incomplete fractures on shafts of the ulnae or clavicles, the characteristic results of falls, were observed in the Raunds sample. The incomplete or "greenstick" fracture is associated with childhood trauma as children are especially resilient to fractures, but the lesion is often difficult to verify without X-ray and even then may be indiscernible. Although children were not examined in this study, the incomplete lesions etched in the adult longbones did not reflect abuse, but more likely a childhood fall, as the injuries were discrete incidents that did not exhibit localized multiple healing, an indicator of abuse in adults and children. This observation, combined with the lack of metaphyseal and spiral shaft fractures, especially to the humerus and tibia caused by yanking and twisting the unfused longbone, would have served as a possible indicator of earlier abuse (e.g., O'Neill et al., 1973; Walker et al., 1997).

The urban comparison

The urban males sustained a greater number of fractures to a variety of anatomical locations, possibly reflecting riskier and more diverse activities when compared to females. The fracture frequency of urban females was also significantly lower than that of the rural group, although the fracture locations were similar. This disparity suggests a difference in general activity and/or environmental conditions, especially between urban females and other groups. Documentary evidence for urban occupations can be determined from a variety of medieval sources such as poll taxes, assessment rolls, court records, registered wills, depositions due to debt, defamation, and marriage records (Goldberg, 1992). Urban male professions included cook, baker, butcher, miller, tailor, carpenter, armorer, and dyer. Women were frequently involved in the sale of produce rather than the actual production, i.e., they were the vendors of bread, but rarely the bakers. In addition to retail trade, traditional female professions included spinster, brewer, seamstress, and laundress (Goldberg, 1992), all of which were more sedentary and less dangerous than the farm chores performed by the rural females or the activities of the urban males.

Fracture trauma among townspeople was minimal, as previously suggested by Grauer and Roberts (1996). They proposed that the trauma pattern of St. Helen-on-the-Walls was comparable to that of other medieval urban sites, in that longbone fractures were uncommon; the radius and/or humerus were the most frequently fractured bones; and

males displayed a higher percentage of trauma. Grauer and Roberts (1996) concluded that the hazards of medieval urban centers were minor. The results obtained in the present investigation support this argument, and show no significant difference between the individual fracture frequencies among the urban groups, although a significant difference exists between the fracture frequencies of the urban and rural samples.

CONCLUSIONS

Fractures at rural medieval British sites were indiscriminately distributed between males and females. The locations and types of fractures, however, do reflect a segregation in activity. This activity, probably associated with labor, was recorded historically and iconographically and provides a possible explanation for some of the injuries observed in this sample. Rural activity has changed little over time, especially when compared to modern "traditional" farming and small-scale operations where some chores are still performed manually. As in the present, all individuals were expected to help out on the medieval farm and therefore were susceptible to farm-related dangers. A high individual fracture frequency is significantly associated with farming in medieval Britain, and suggests that this type of environment was more hazardous than that of urban neighbors, just as it is today.

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